THE DESIGN AND EQUPMENT OF A METALLOGRAPHIC POLISHING MACHINE

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The Design and Equipment of A Metallographic Polishing Machine

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THE DESIGN AND EQUIPMENT OF
A METALLOGRAPHIC POLISHING MACHINE.

IMPORTANCE OF METALLOGRAPHY-

In the modern development of the iron and steel industry, the science of metallography along with that of chemistry has played a very important part. The work of the chemist would have been far less valuable without the additional information given by the microscope. Given a piece of steel the chemist could quickly tell what its ultimate analysis might be. He could tell that it contained so much iron, so much carbon, and so much of other elements, but with regard to its ductility, its tensile strength, and its hardness he could say very little. Of the physical properties of metals which make them so important industrially, fully as much has been learned from the proximate structural analysis as revealed by the microscope as from the ultimate analysis of the chemist.

It has been found that metals free from impurities, in cooling from the liquid state, gen-

erally solidify in the form of crystalline grains, the outlines of which can be seen under the microscope on a surface which has been properly polished and lightly etched. Deeper etching will cause the faces of the different grains to reflect different colors, each grain being differently orientated with respect to the general surface. Still deeper etching often brings out pits of distinct geometric form, usually cubic, indicating that a majority of the metals crystallize in the cubic system. The dimensions and characteristics of the grains will depend upon the mechanical treatment that the metal has received, whether it has been cast or forged, worked hot or cold, whether or not it has been under strain; also upon its thermal treatment, such as the degree to which it has been heated and its rate of cooling.

The presence of very small quantities of impurities may have a very marked effect upon some of the important properties of the metal. If the impurity is dissolved by the metal, or forms a chemical compound which is dissolved, and remains

in solution when the metal solidifies, the grains will still appear homogeneous and very little change will be noted in the physical properties of the metal. If the impurity is not dissolved, or forms a compound that is not dissolved, the grains will not be homogeneous and the effect on the physical properties will be very marked. The impurity may not be rejected as such but may unite mechanically with a small amount of the metal to form a eutectic alloy, an alloy of lowest melting point. This alloy usually forms a sort of matrix in which the grains of higher melting point are imbedded.

A good example of the action of an impurity on a metal is found in the behavior of steel, which is principally an alloy of iron with less than 2 % of carbon. The carbon unites chemically with a part of the iron to form an iron carbide of the formula Fe_3C. The eutectic alloy of this carbide and iron, known as pearlite, contains about .85 % carbon. If steel containing less than .85 % carbon is heated above its critical range of temperature and allowed slowly to cool, the

microscope will show the steel to be made up of pure iron, or ferrite, and pearlite. This steel would be soft and ductile. If the carbon content were more than .85 %, and the steel were heated above its critical range and slowly cooled, it would be found to be made up of pearlite and cementite, a form of the iron carbide. If the steel were cooled quickly from the critical range sorbite might be formed. Then the steel would be hard, strong, and elastic, but not very ductile. Other carbon and steel alloys that may be formed, depending upon the mechanical and heat treatment that the steel may receive, are austentite, martensite, and trootsite. The presence of other metals, such as tungsten, vanadium, chromium, nickel, manganese, and molybdenum, affects the steel in various ways. It has been found that if steel is subjected to a certain critical stress the grains will appear larger than where the stress is either greater or less.

All of these effects can be observed under the microscope and from the knowledge thus gained it is possible to produce and duplicate steel and

other metals of desired properties. For reasons such as this the science of metallography is coming to a more and more important position.

EQUIPMENT FOR METALLOGRAPHIC LABORATORY.

THE MICROSCOPE AND ACCESSORIES-

The principal piece of apparatus needed in a metallographic laboratory is the microscope. While it is possible to use any good instrument of the ordinary type, there are special features that are very desirable in one used for the examination of opaque objects.

In the first place, it is possible to examine metal specimens only with reflected light. With a low power objective one can use oblique illumination obtained either by allowing daylight or artificial light to fall freely on the object or by directing the light by means of mirrors, reflectors, or condensers. With high power objectives it is necessary to use vertical illumination produced by a mirror, a totally reflecting prism, or a transparant reflector, placed within the tube of the microscope.

The illumination of opaque objects requires an intense source of light, such as an electric arc, a gas filled electric filament light, or a Welsbach gas lamp. Of these, the Welsbach light is the cheapest, while the electric arc with the carbons at right angles is the most intense. In addition to the light itself, a condensing system is needed to collect the light rays and focus them upon the reflector.

In taking photographs it is often desirable to use a monochromatic source of light, such as the mercury lamp, or to obtain monochromatic light by means of color screens, green being the color generally used.

Ordinary microscopes, built for examination by transmitted light, are equipped with fixed stages. Adjustments are made by moving the objective up or down. With vertical illumination, where the objective must remain in a fixed position with respect to the source of light, an adjustable stage is desired. It is also an advantage to have a mechanical stage making it possible to bring any desired portion of the surface

under examination or to examine the whole surface uniformly.

Some form of holder must be provided to hold the surface being examined perpendicular to the optical axis of the instrument. If the specimen is simply set upon the stage it means that two of its surfaces must be machined parallel. If the specimen is iron or steel, a magnetic holder can be used. If it is small it may be imbedded in wax. With reflected light it is better not to use a cover glass.

In order to take microphotographs it is only necessary to add a suitable camera. There must be a light tight connection between the camera and the microscope. It is best to have microscope, illuminator, and camera all mounted on the same base.

Because of its compactness the inverted microscope has found considerable favor. With this instrument the specimen rests upon a stage above the microscope which is pointed upwards.

FURNACE AND PYROMETER.

In studying the effect of heat treatment on

iron and steel a small gas or electric furnace and a pyrometer will be found to be very useful.

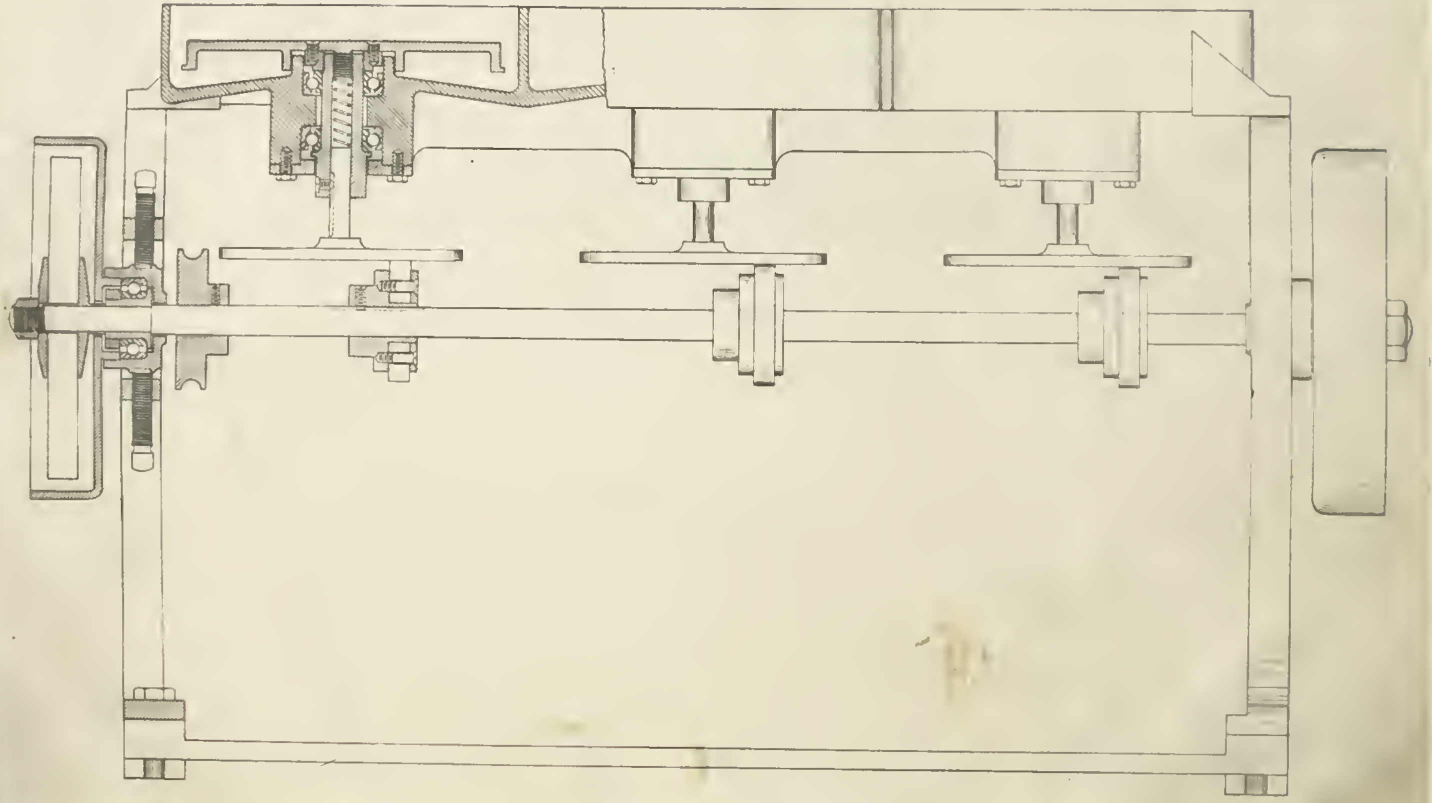
POLISHING MACHINE.

All that is needed to complete the equipment of a metallographic laboratory is some form of apparatus for polishing the specimen.

If this is to be done by the slow and laborious hand process, four wooden blocks, two covered with canvass and two with broadcloth, and the necessary polishing materials are all that are needed.

The great care required in the polishing process by no means eliminates the possibility of speed with the proper equipment. There are several machines on the market consisting of revolving disks, either vertical or horizontal, driven by a suitable source of power. One form of machine uses a reciprocating motion and still another that is finding very general favor uses an endless belt covered with polishing material.

The machine shown in the drawing accompanying this thesis was designed and built for use in



METALLOGRAPHIC POLISHING MACHINE

the Mechanical Testing Laboratory of Armour Institute of Technology. It is a machine of the Wysor type having two grinding wheels revolving in vertical planes and three polishing disks revolving in a horizontal plane. The source of power is an electric motor.

To make the machine run as smoothly as possible the disks have been dynamically balanced, mounted on ball bearings, and connected with the source of power thru flexible couplings.

The disks are covered with canvass or broadcloth held in place by a ring. With them in a horizontal position it is an easy matter to apply the polishing material in the form of a thin paste. Drains have been provided to remove any surplus water. The frame has been so designed that the water will drain away from and not towards the bearings.

ABRASIVES AND POLISHING MATERIALS.

Before giving the polishing process in detail it might be it might be well to give some recommendations with regard to abrasives and pol-

ishing materials. Because abrasives are always harder than the surface upon which they are used their action is to wear away the surface by cutting. Surfaces prepared by the use of abrasives only may present a polished appearance to the naked eye but will not be suitable for microscopical examination because of furroughs and other imperfections. Polishing materials are usually softer than the metal upon which they are to be used. Their action is not to cut,but to rub, producing a surface flow that gradually closes over the furroughs produced by abrasives.

Emery is the natural abrasive most commonly used. Two products of the electric furnace that are so used are fused crystalline aluminum oxide, sometimes known as alundum, and synthetic silicon carbide, better known by such trade names as carborundum or crystolon.

Grinding wheels are manufactured by processes known as vitrified, silicate, elastic, and rubber. The essential differences are due to the bonds used. The vitrified wheel bonds are mineral or clay mixtures which, at high temperature,

fuse either to a glass or vitrified porcelain matrix. The silicate bond is a mixture of silicate of soda and minerals which, at comparatively low temperatures, form a hard cement. The elastic wheel bonds are organic materials which melt at low temperatures but which attain a permanent set at slightly higher temperatures. The rubber wheel bonds are composed of rubber mixed with mineral constituents in definite proportions to produce by vulcanization a desired hardness and toughness.

The size of the grain is indicated by numbers from 10 to 200 according to the number of meshes per lineal inch in the screen thru which the grains were sifted. Grains finer than 200 are sorted by hydraulic means and indicated by a combination of letters and numbers.

Grade is a term used to denote hardness. It represents a measure of the strength of the bond or the cohesive force exercised by the bond to retain the grain in its setting. Vitrified wheels are graded from F to Z, elastic wheels from 1 to 7, F and 1 representing the softest

grades.

For preparing specimens of steel and other metals of high tensile strength it is best to use Alundum wheels of fine grain and medium grade. For such metals as cast iron crystolon wheels are very effective. Very fine crystolon wheels tend to produce a semi-polish or burnished effect.

For the initial grinding Saveur uses a grain 80, grade P Alundum Vitrified Wheel. For the final grinding he uses a grain 200, grade M Alundum Vitrified Wheel. Wysor uses a grain 46, grade 3 Crystolon Elastic Wheel for the initial process and a grain F or XF, grade M, N, or O for the final grinding.

The most common polishing materials are the unfused oxides of aluminum, magnesium, iron, and chromium, better known by such names as Tripoli Powder, French Chalk, rouge and so forth. One of the best agents for fine polishing is fine alumina powder prepared by the process of levigation. A certain amount of alumina powder is suspended in a large volumn of water, well shaken, and allowed to stand for five minutes. The liquid

with alumina still in suspension is then siphoned off and is suitable for polishing purposes. For finer powders the liquid that is siphoned off is allowed to stand for a longer period and the process is repeated.

THE POLISHING PROCESS.

The examination of the microstructure of a metal requires that its surface be cut or ground flat, brought to a high polish, and finally etched.

The first step in the way of preperation is to saw off a piece about ½" square and ¼" thick. If the metal is too hard to saw a piece may be broken off with the hammer.

In order to make it easier to handle the piece may placed in a holder filled with sealing wax, plaster of paris or some low melting alloy. Saveur mentions such an alloy consisting of 50 parts bismuth, 30 parts lead, 25 parts tin, and 3 parts zinc. This alloy melts below 100 deg. C.

The surface to be examined is then ground smooth using a wheel that is not too coarse and

that will not scratch too deep. If the piece is very rough or has a tough outer scale it would probably be better to do the grinding on several wheels of different grades.

A smoother finish can be obtained by using a canvass disk covered with emery flour and water.

The polishing is done on disks covered with broadcloth using one of the polishing agents mentioned.

The structure of some metals can be brought out by polishing in relief. This is done by using the polishing material on a soft yielding support such as chamois skin stretched over wood. By this method the softer elements of the metal are dug out and the harder are left standing.

In the polishing of the specimen there are several points that it would be well to remember:

1. After each grinding or polishing process the specimen should be rotated 90 degrees so that each abrasive will remove the marks left by the one used before it.
2. After each process wash the specimen

in running water to remove all grit and loose material. Dry in an air blast, preferably warm.

3. Use only a fine texture cloth or felt. Coarse threads and ridges will cause scratches.

4. Do not press too hard to hasten results. Pressure tears down and deforms the surface to a considerable depth. Burnishing is simply an exaggerated case of surface flow or deformation. It can be produced this way and often misleads beginners because of its lustrous finish.

The microscopic examination of a polished sample would reveal the presence of such inclusions as graphite and slag and, if relief effect is produced, the presence of constituents considerably harder than the matrix. However, all of the surfaces being equally bright, the surface would act as a mirror and very little information could be gained. Etching the surface with acids affects the different constituents in different manners or to different degrees and makes it

quite easy observe the structure of the metal.

The details of the surface can also be brought out by electrolosis. The presence of phosphorous may be detected by heat tinting and that of sulphur by sulphur printing. For some purposes a combination of polishing and etching known as polish attack is very effective.

The precesses that have been described are those generally used in preparing metal specimens for examination under the microscope. If it is desired to keep the specimens for repeated observation all that is necessary is to cover the surface with parafine or oil.

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